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Noise measurements in self-oscillating mixers

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### Abstract

Noise measurements on the self-oscillating mixer at 60 GHz have been made in both GaAs and InP Gunn devices. These devices were fabricated using an image guide design as the transmission media. The double side-band noise figure and conversion characteristics were measured and it is shown that the noise performance of these devices make them attractive for application where low cost, simplicity in circuitry, and small physical size are important factors.

### Introduction

Over the past several years considerable interest has been shown in the millimeter wave self-oscillating mixer.<sup>1</sup> The main reason for this concern is its simplicity of design and reduction in complexity of the receiving electronics. Traditional approaches to receiver front-end design have usually taken the route of using tuneable separate local oscillators for the down-converter. Although this technique offers the highest sensitivity, realistic cost appraisals may ultimately force some trade-offs with respect to cost and sensitivity, especially where broad bandwidths or high power environments are contemplated. Many of the planned high-volume systems applications fall into this category and will require simple, low cost high burn-out mixer elements.

In addition to its low cost high burn-out resistant mixing properties, another important characteristic of the self-oscillating mixer is its noise behavior. In this paper a comparison of the noise figure of GaAs and InP Gunn diode self-oscillating mixers are reported.

### Device Design

A prototype planar integrated device illustrates how the high resistivity image guide is adapted to present day state-of-the-art Gunn devices. Figure 1 depicts an exploded view of the device and shows the small number of parts required. The fundamental electro-magnetic wave propagating in a dielectric image line is the  $E_{11}$  mode, a hybrid mode. Application of theoretical considerations indicated that the dielectric waveguide for proper operation should be on the order of one half to one wavelength in the medium in height.<sup>2</sup> At 60 GHz, it was found that with the Gunn diode imbedded in the dielectric ( $Al_2O_3$ ), the cross-sectional dimensions of the dielectric guides could be made oversized, i.e., slightly greater than 1 millimeter in height and about 2 millimeters in width. Experiments indicated that in this over-sized condition, the  $E_{11}$  mode was dominant. Referring to fig. 1, the metal housing was designed for minimum radiation with dimensions that are not critical for proper operation. This design allowed the dielectric image line coupling to the metal waveguide to be fixed in one position. A brass cover piece with a smooth transition from the dielectric height to regular V-band waveguide optimized the impedance match and gave repeatability of measurements.

### Results

Figure 2 shows the actual power output and frequency of an InP Gunn diode as a function of the bias voltage. Figure 3 indicates how the optimum power and frequency of this device varies as a function of the tuning short position. Figure 4 shows the conversion characteristics for the InP self-oscillating mixer as a function of bias voltage. The InP diode gave a conversion gain in the order of 10.0 dB instead of a loss. This is typical of the behavior observed with the self-mixing Gunn diodes. To obtain gain, the bias voltage is adjusted to point just above the threshold for oscillation. With further increases in the bias voltage, the conversion gain characteristic decrease and turn negative (conversion loss) at the high end of the bias voltage range. Figure 5 shows the minimum detectable signal for the GaAs image guide self-oscillating mixer. The minimum detectable signal is -72 dBm at a bias voltage of 2.6 volts, which is just above the threshold for oscillation. As the bias voltage was increased, the minimum detectable signal increased monotonically. Figure 6 shows the minimum detectable signal for a InP self-oscillating mixer as a function of bias voltage. For the InP device, the minimum detectable signal decreased to -79 dBm.

This represents a rather sizeable increase in sensitivity for the self-oscillating mixer and may point the way to develop more applicable devices for systems applications. A minimum noise figure of 19.0 dB was calculated for the GaAs device compared to 12 dB for the InP device. As the bias voltage increased, the DSB noise figure tends to increase. Proper operation of this device would dictate that a voltage point of just above threshold for oscillation should be used.

### Conclusions

In terms of noise figure the data indicates that the InP self-mixing oscillator's sensitivity is better than that of the GaAs device. In general, theory predicts that InP semiconductor material possess intrinsic properties that make it a superior material for the fabrication of millimeter wave Gunn devices. The 12.0 dB noise figure measured on the InP self-mixing oscillator, as compared to 19.0 dB for GaAs, seem to confirm some of these theoretical predictions.

### Acknowledgements

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### References

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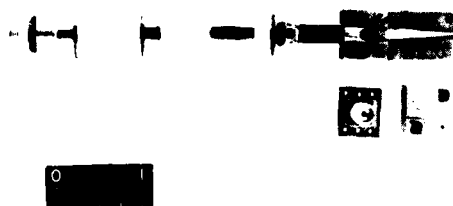


Figure 1 - Exploded View of Self-oscillating mixer

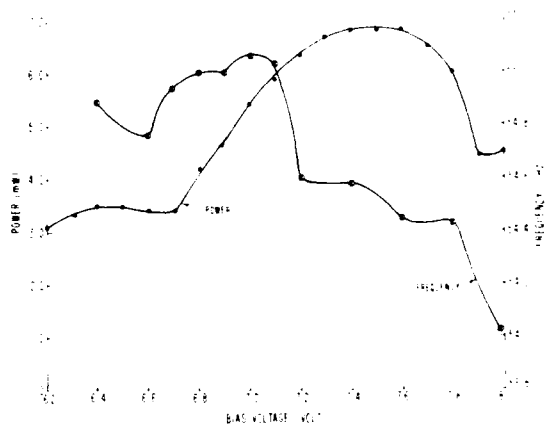


Figure 2 - Output power and frequency as a function of bias voltage

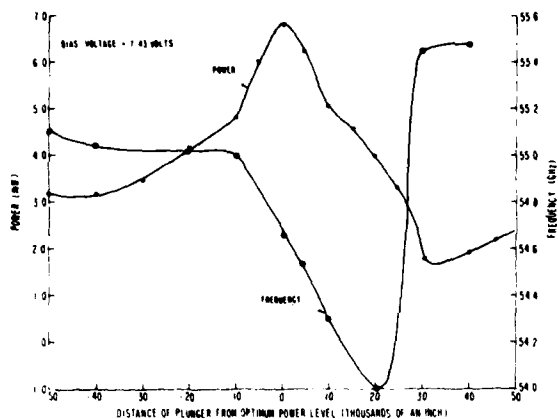


Figure 3 - Output power and frequency as a function tuning short position

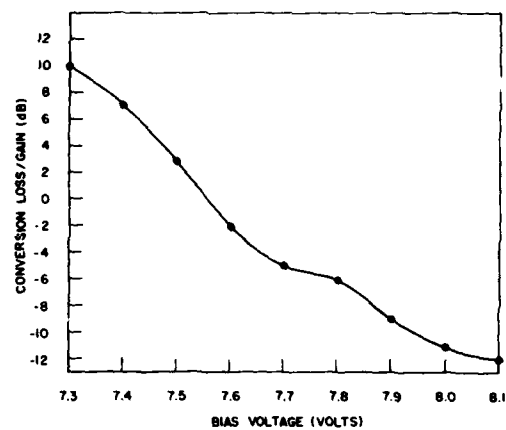


Figure 4 - Conversion characteristics on InP self-oscillating mixer

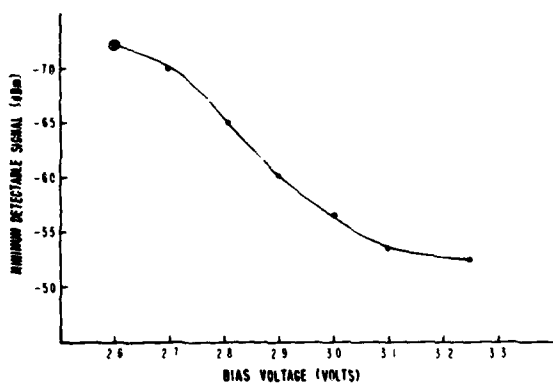


Figure 5 - Minimum detectable signal for GaAs self-oscillating mixer

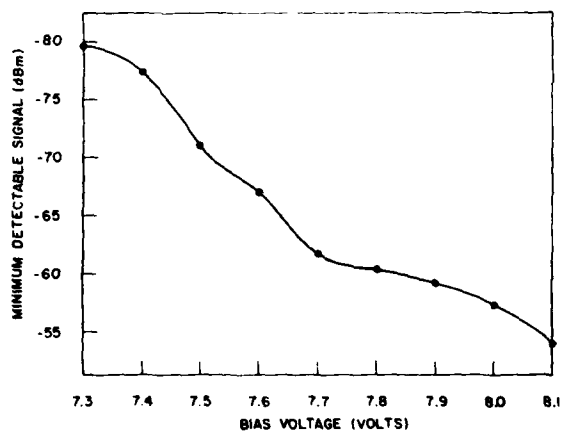


Figure 6 - Minimum detectable signal for InP self-oscillating mixer